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| 論文題目 | The factor analyses concerning the infiltration of radioactive Cs for the effect of forest decontamination activities and the development of the evaluation method for the residual radioactive Cs on surfaces（放射性セシウムの浸透等が森林除染の効果に及ぼす要因の分析及び表面残存状況の評価方法の開発） | | |

（論文内容の要旨）

Extensive area, from northern part of Tohoku to southern part of Kanto was contaminated by radioactive substances released by nuclear accident happened in Mar. 2011. In this research, effects of the characteristics of the infiltration of radioactive Cs to the forest decontamination activities are analyzed and the evaluation method of the residual radioactive Cs on ground surfaces are developed.

**Chapter 1** Introduction describes the background that motivates this research to be carried out, the objectives, the study area and the systematics of this research.

**Chapter 2** The accident of Fukushima dai-ichi nuclear power plant, situation of radioactive Cs contamination in Fukushima, and the decontamination activities are reviewed.

**Chapter 3** Based on decontamination data on the surface dose rate, air dose rate, and surface contamination concentration (hereinafter referred to as the “radiation dose”), the relationships of the decontamination effect with the “pre-decontamination radiation dose,” “monitoring term of pre-decontamination,” and “types of vegetation” were analyzed. Higher pre-decontamination ranges corresponded to higher rates of radiation dose reduction, but the reduction almost stabilized once the radiation dose reached a certain level. Background radiation was assumed to exert a stronger influence on the decontamination effect in forest areas. The rate of radiation dose reduction decreased as time passed, even under high radiation conditions in the later monitoring term, though some fluctuation in the rate was seen. Finally, the reduction rate varied among different types of vegetation observed through analyses using GIS data. The rate was much higher, for example, in deciduous conifer plantation compared to other types of vegetation. Additional on-site fieldwork revealed that the variable levels of radioactive Cs infiltration in vegetation might be linked to differences in the decontamination work performed. Temporal changes of the depth profiles presumably influenced the decontamination effect, given the basic method of decontamination mainly by removing the leaves, branches, and other organic matter.

**Chapter 4** Soil core samplings were conducted in 5 points with different vegetation in Fukushima Prefecture in order to explore saturated hydraulic conductivity, field capacity and voidage. Depth profiles of radioactive Cs, ignition loss and CEC (Cation Exchange Capacity) in the 5 forest soils were also

investigated, making use of scraper plate (at 0.5 cm intervals for 0-5 cm and at 1.0 cm intervals for 5-10 cm). Depth profiles in soil layers were totally different between forests and explicit relation could be confirmed neither for field capacity, voidage nor ignition loss. On the other hand, CEC correlated weakly and saturated hydraulic conductivity did strongly with infiltration of radioactive Cs. Compartment modeling was conducted, to try to duplicate the monitored depth profile, taking ignition loss as a parameter, based on the experiment result that ignition loss had positive correlation with CEC, which might influence the adsorption process on radioactive Cs in soil layer. However, only the ignition loss couldn't fully reproduce the depth profile. In the wake of the result as well as the fact that saturated hydraulic conductivity might have explicit relation with infiltration of radioactive Cs, factors related with precipitation or water flow in early stage after the accident could influence the depth profile, before adsorbed with negative charge in soil particles. Relation between the infiltration of radioactive Cs and the characteristics of soil could be guessed according to the results of this Chapter, though additional research must be conducted to grasp the phenomena especially in early stage after the fallout of radioactive Cs.

**Chapter 5** Scatter plots based on the monitoring data showed that at the surfaces of paved roads, surface contamination concentration indicated high values even in the low surface dose rate circumstances. On the other hand, at the surfaces of forests and unpaved roads, surface contamination concentration indicated low values even in the high surface dose rate circumstances. "SRI value", which was defined to represent the residual radioactive Cs at surfaces, referred that in the forests and unpaved roads, SRI values tended to gradually decrease and much smaller than those of paved roads. It has been assumed that radioactive Cs had already penetrated toward the underground to some extent and continuously moved downward, after 1.5 years have passed since the nuclear power plant accident. On the paved roads, SRI values set up the possibility that radioactive Cs still remained on the surfaces, however, has infiltrated slowly towards the end of monitoring term. SRI values possibly evaluate the depth profile of radioactive Cs in forest soils with different types of vegetation, because β value, which indicates the degrees of penetration of radioactive Cs, and residual condition of radioactive Cs in organic layer, showed correlation with SRI values. They are thought to be effective to grasp the rough residual condition of radioactive Cs quickly on the site of decontamination activities.

**Chapter 6** All the important findings are summarized and emphasized. Finally, future tasks and prospects are also described.

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（論文審査の結果の要旨）

本論文は､福島第一原発事故で放出された放射性セシウムによって汚染された森林や道路を除染した場合の効果について、環境省が保有する大量のデータと、現地調査結果を解析することで、除染効果と、放射性セシウムの地中分布に影響を及ぼす因子について検討を行ったものである。得られた主な成果は以下のとおりである。

１） 森林除染に係る空間線量率等のデータから、除染前の空間線量率等が高いほど除染による空間線量低減率は高くなったが､ある程度の空間線量率以上ではほぼ一定となることを示した。このことから、特に低い線量帯では除染効果が周囲の空間線量率の影響を強く受けることが示唆された。

２） 除染による空間線量低減率は除染時期が遅くなると全体的には減少傾向にあることを示した｡このことは時間の経過とともに放射性セシウムが徐々に地下に浸透することで､除去する堆積有機物に含まれる放射性セシウムの量が減少し、除染効果も低減する可能性を示している。

３） GIS を活用し、植生ごとの空間線量率等の低減率の差を分析した結果、落葉針葉樹林の場合の 1cm 空間線量率、100cm 空間線量率、表面汚染密度の低減率はそれぞれ約 53%、約 34%、約 59%であり、常緑針葉樹植林ではそれぞれ約 26%、約 22%、約 29%であった。環境省の除染関係ガイドラインに基づく方法で森林除染した場合、森林部における空間線量率等の低減率は高くても半分程度であり、また、樹種による違いが大きいことを示した。

４） 地表面における放射性セシウムの残存状況を示す指標（SRI 値）を定義し、経時変化を確認したところ、森林や未舗装道路では、放射性セシウム沈着後 1 年半程度が経過した段階では、既に放射性セシウムは土壌等の表面にはほとんど存在せず、地表部までβ線がほとんど出てこない深度以上に地下浸透しており、一方、舗装道路では、依然として表面に残存し，β線が地表部で観測されている可能性を示した。これらの結果より、除染作業の際に使用する 1cm 空間線量率や表面汚染密度を測定する機器を用いて、地表面における放射性セシウムの残存状況を簡易に評価できることを示した。

以上のように本論文は、森林域などでの除染効果を推定する上での有用な情報と、放射性 Cs の地中分布を簡易に推定する方法を提供するものであり、今後の空間線量の将来予測と、効率的な除染計画の策定に大きく貢献するものであって、学術上、実際上寄与するところが少なくない。よって、本論文は博士（工学）の学位論文として価値あるものと認める。また、平成３０年１月２３日、論文内容とそれに関連した事項について試問を行って、申請者が博士後期課程学位取得基準を満たしていることを確認し、合格と認めた。